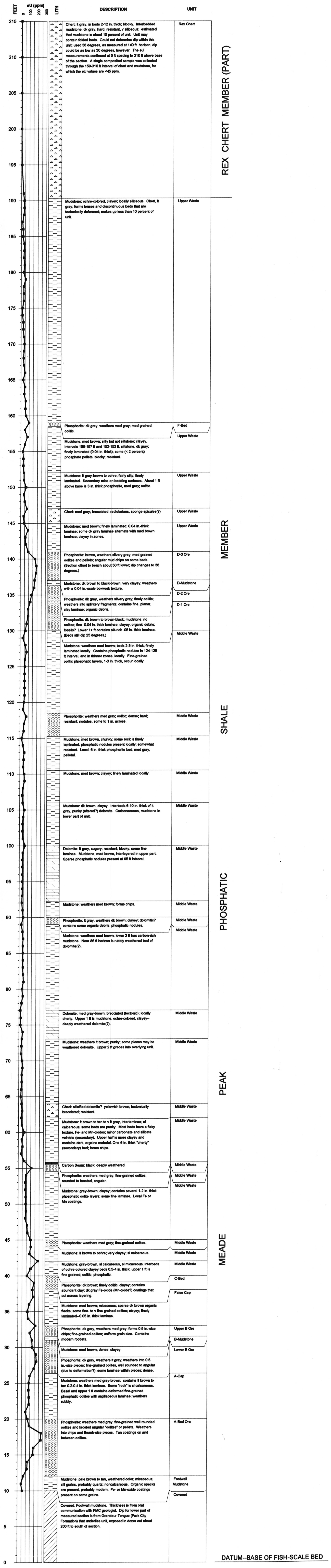
U.S. DEPARTMENT OF INTERIOR
U.S. GEOLOGICAL SURVEY

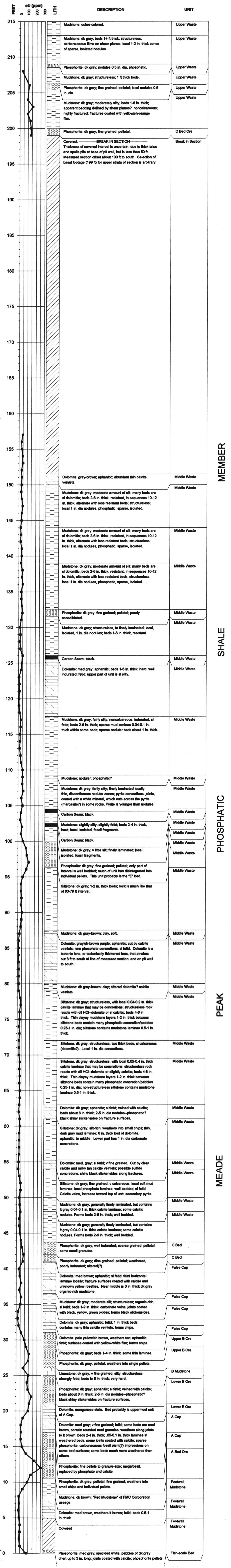
WESTERN PHOSPHATE PROJECT Page 1 of 1

Section: wpsC — Date Measured: 10/6-7/98 — Sec-Twn-Ra: Sec. 5, T. 8 S., R. 44 E.
Formation: Phosphoria — Lat: 42 deg., 45.11' N.
Member: Meade Peak Phosphatic Shale — Long: 111 deg., 20.37' W.
Measured By: Tysdal, Grauch, Desborough, Herring, Stillings — Quadrangle: Upper Valley
Notes: - — Mine: Dry Valley



WESTERN PHOSPHATE PROJECT Page 1 of 1

Section: wpsD — Date Measured: 6/23-25/99 — Sec-Twn-Ra: Sec. 5, T. 8 S., R. 44 E.
Formation: Phosphoria — Lat: 42 deg., 45.07' N.
Member: Meade Peak Phosphatic Shale — Long: 111 deg., 20.37' W.
Measured By: Tysdal, Desborough, Herring, Grauch — Quadrangle: Upper Valley
Notes: -- — Mine: Dry Valley



INTRODUCTION

The U.S. Geological Survey (USGS) has studied the Permian Phosphoria Formation in southeastern Idaho and the entire Western U.S. Phosphate Field throughout much of the twentieth century. In response to a request by the U.S. Bureau of Land Management, a new series of resource, geological, and geoenvironmental studies was undertaken by the USGS in 1998. To accomplish these studies, the USGS has formed cooperative research relationships with two Federal agencies, the Bureau of Land Management and the U.S. Forest Service, tasked with land management and resource conservation on public lands; and with five private companies currently leasing or developing phosphate resources in southeastern Idaho. The companies are Agrium U.S. Inc. (Rasmussen Ridge mine), FMC Corporation (Dry Valley mine), Rhodia Inc. (Wooley Valley mine—inactive), J.R. Simplot Company (Smoky Canyon mine), and Solutia Inc. (Enoch Valley mine). Some of the mineralogical research associated with this project is supported through a cooperative agreement with the Department of Geology and Geological Engineering, University of Idaho.

Present studies consist of integrated, multidisciplinary research directed toward (1) resource and reserve estimations of phosphate in selected 7.5-minute quadrangles; (2) elemental residence, mineralogical and petrochemical characteristics; (3) mobilization and reaction pathways, transport, and fate of potentially toxic elements associated with the occurrence, development, and societal use of phosphate; (4) geophysical signatures; and (5) improving the understanding of deposit origin. Because raw data acquired during the project will require time to interpret, the data are released in open-file reports for prompt availability to other workers. Open-file reports associated with this series of studies are submitted to each of the Federal and industry cooperators for technical review; however, the USGS is solely responsible for the data contained in the reports.

MEASURED SECTIONS

Stratigraphic sections of the Phosphoria Formation were measured and sampled by the USGS at several places in southeastern Idaho. The sections, generally lacking interpretation and explanatory notes, are published as preliminary reports as they are assembled. No thin section, X-ray, or analytical technique other than gamma-ray spectrometry has been used to augment the field descriptions of the rock units in this report. The descriptions are accompanied by a computer-generated lithologic log. Informal bed names used at the Dry Valley mine are shown in the unit column. Contacts of units within the ore zones were picked by mine personnel; those within the middle and upper waste zones generally were picked by USGS personnel. The units within the measured sections were sampled for geochemical and petrological analysis and also were evaluated with a variety of geophysical techniques. English units of measurement are used throughout this report to facilitate direct correspondence with units in the extensive historical literature on the Phosphoria and with current industry usage.

The Phosphoria Formation in the vicinity of the measured sections consists of three members, which in ascending order are the Meade Peak Phosphatic Shale, the Rex Chert, and the informally named cherty shale (McKelvey and others, 1959; Hale, 1967; Rioux and others, 1975). The measured sections of this report focus on the Meade Peak Phosphatic Shale Member. The Meade Peak unconformably overlies the Grandeur Tongue of the Permian Park City Formation, and the cherty shale member is overlain by the Triassic Dinwoody Formation. Both sections were measured at essentially the same geographic position, but section wpsC (western phosphate section C) was of rock about 150 ft higher in elevation than that of section wpsD, and much closer to the land surface that existed just prior to mining. Measuring a pair of sections close together, but at different depths below this land surface, permits evaluation of important effects of weathering on rock geochemistry. Measurements record true thickness. Adjustments were made for dip of beds at the time of measurement. Except for upper waste strata of wpsD, the two sections were measured on horizontal surfaces exposed by mining equipment. The two sections are of similar thickness, as expected. The upper ore zone of section wpsD was not exposed on the floor of the open-pit mine because it was mostly covered by talus and waste-pile debris at the base of the pit wall. Waste above the upper ore zone of wpsD was measured on the pit wall.

EQUIVALENT URANIUM (eU)

Each of the two sections is accompanied by a profile of the equivalent uranium (eU) measurements taken with a gamma-ray spectrometer. Concentrations of eU are given in parts per million (ppm). Section wpsC was measured with an Exploranium GR-320 and section wpsD was measured with a GAD-6. These instruments measure gross gamma-ray flux (including cosmic rays) and provide a quantitative measure of K, U, and Th. Determination of the abundance of U and Th occurs via detection and counting of gamma rays of specific energy associated with a particular daughter radionuclide for each element, ^{214}Bi with a 1.76 MeV (million electron volt) gamma-ray in the case of uranium. Calculation of total abundance of U and Th assumes secular equilibrium between the measured daughter nuclide and the parent isotope and all intermediate daughter nuclides for each individual element. Potassium abundance is determined from the measurement of gamma rays associated with the decay of ^{40}K. The spectrometer integrates detection over a 2π geometry of approximately 1/2 m^3 and has proportionally higher detection sensitivity to those gamma rays that are emitted closer to the detector. The calibration equations for the two spectrometers assume this geometry on a planar surface and are based on analysis of concrete pads of known composition of the three elements. The calibration coefficients, as well as the constants for subtracted background counts, are a function of latitude, altitude, rock density, and moisture. The coefficients become less reliable as location and rock conditions change from those of the calibration.

In Tysdal and others (1999), we plotted eU concentration data after normalization of the highest eU concentration of section wpsA, 373 ppm, to 200 ppm and of section wpsB from a high of 468 ppm to a scaled high value of 282 ppm. For the eU data graphed in Tysdal and others (1999), the original eU measurement can be extracted from the plotted values by multiplying by scaling factors of 1.87 for section wpsA and 1.66 for section wpsB. This scaling was done because published reports from the 1970's and earlier on uranium and eU concentrations in the Meade Peak Phosphatic Shale Member state that few uranium concentrations from this member exceed 200 ppm (see Swanson, 1970, and references therein) and we had little independent check on accuracy of the spectrometer data. However, new analytical data as part of our study question these past published relationships.

Recently, we re-analyzed a subset of samples using delayed neutron (DN) analysis, which has a precision of better than 3 percent and an accuracy of generally better than 5 percent (McKown and Millard, 1987). The relationship between the two measurement techniques is shown in figure 1 for 70 samples. The DN analysis can be used to assess the uranium concentration data in Herring and others (1999), which were obtained using inductively-coupled plasma atomic emission spectroscopy (ICP-AES) measurements with a lower detection limit of 100 ppm. For a common set of 12 samples where ICP-AES measurements indicate uranium concentrations greater than the detection limit of 100 ppm, the DN analysis shows that ICP-AES measurements average 12 percent greater than those of DN and have a relative standard deviation of 12 percent. Given this relative credibility in the ICP-AES technique as verified by DN analysis, the frequency of uranium concentrations >100 ppm among the set of all composited stratigraphic samples of the Meade Peak consequently can be estimated. For 182 channel samples from sections wpsA, wpsB, wpsC, and wpsD as measured by ICP-AES, 18 percent of the uranium concentrations are >100 ppm, 16 percent are between 100 and 200 ppm, and 2 percent are >200 ppm. These channel samples average concentrations over intervals from 1 to 15 feet of true stratigraphic thickness. Clearly, each channel sample will have some uranium concentrations that are indeed higher, perhaps considerably so, than the interval average. Consequently, we believe that uranium concentrations in excess of 200 ppm are not as uncommon as reported by Swanson (1970, and references therein) and that uranium concentration measurements from the gamma-ray spectrometers are reasonably correct and should be reported as measured rather than scaling them against an assumed upper limit value.

Previous studies of the Phosphoria Formation maintain that there is a consistent relationship between eU and total uranium contents and between total uranium and phosphate contents (McKelvey, 1956). Our measurements indicate considerable scatter in both relationships (fig. 1; Herring and others, 1999; Herring, unpub. data). Measured eU concentrations, even between adjoining 1 foot intervals of consistent lithologic character, often exhibit considerable variability. We expect that this results from: (1) fine-scale variability in the concentration of uranium; (2) the effect of the geometry of the dipping rocks; or (3) from lack of secular equilibrium. Scatter in the U to P_2O_5 relationship results from uranium removal or addition by syndepositional effects and (or) by post-depositional alteration, especially weathering. The uranium is mostly located in the phosphate mineral lattice as a substitute for Ca; location of the decay (daughter) products is uncertain. For the phosphatic rocks of the Phosphoria Formation, total gamma counts are dominated by decay of uranium and its various daughter products. K_2O is generally $\leq$1 percent in the phosphorite and <3 percent in the middle waste shale; Th concentrations are generally $\leq$15 ppm in ore and waste shale (Altschuler and others, 1958; Swanson, 1970; Herring and others, 1999; Herring, unpub. data).

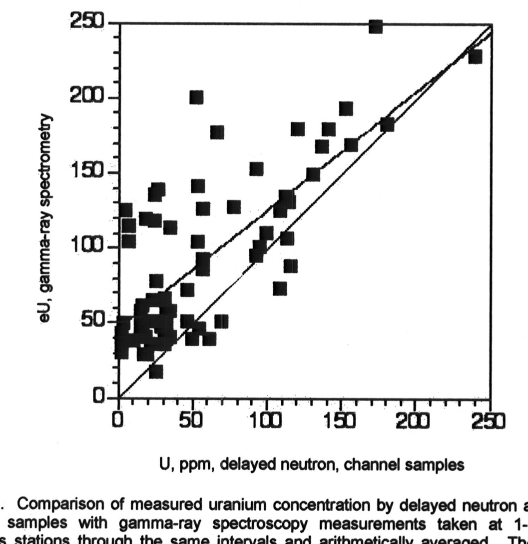


Figure 1. Comparison of measured uranium concentration by delayed neutron analysis in channel samples with gamma-ray spectroscopy measurements taken at 1-foot true-thickness stations through the same intervals and arithmetically averaged. The 1:1 and least-squares regression (R^2 = 0.55) lines are shown.

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ACKNOWLEDGMENTS

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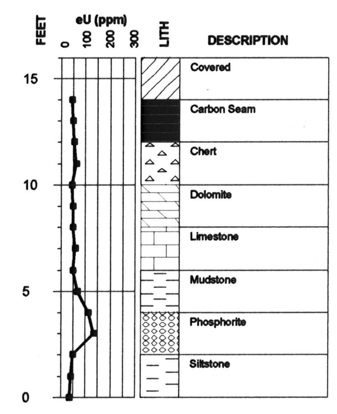
EXPLANATION

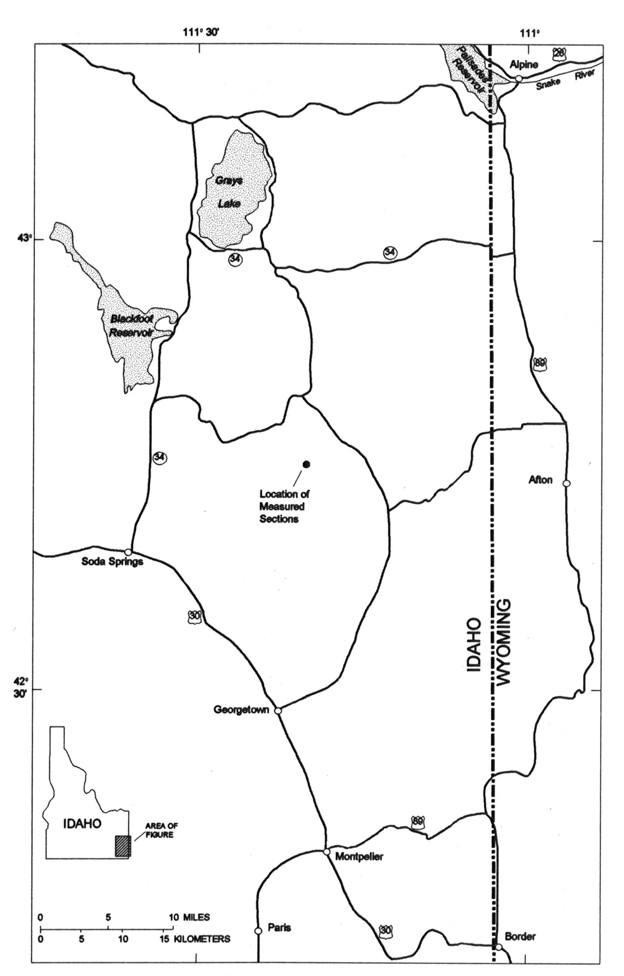


ABBREVIATIONS

dia	diameter
dil	dilute
dk	dark
eU	equivalent uranium
ft	feet
in.	inches
lith	lithology
med	medium
ppm	parts per million
sl	slightly
v	very

CONVERSIONS

Some thin layers within the stratigraphic sections originally were measured in millimeters, then converted to English units. A thickness of 1 millimeter converts to 0.04 inches, implying a measurement precision greater than actually exists.



INDEX MAP SHOWING LOCATION OF MEASURED SECTIONS

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U.S. Bureau of Land Management
U.S. Forest Service
Agrium U.S. Inc.
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J.R. Simplot Company
Rhodia Inc.
Solutia Inc.

STRATIGRAPHIC SECTIONS AND EQUIVALENT URANIUM (eU), MEADE PEAK PHOSPHATIC SHALE MEMBER OF PERMIAN PHOSPHORIA FORMATION, DRY VALLEY, CARIBOU COUNTY, IDAHO

BY
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